Status Report of Action Item 3 Subteam

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Action Item 3

- Articulate the capability demos that need to be done to make human mission to Mars feasible and affordable. Identify if these demos should be done on a) Mars robotic mission, b) the Moon, c) the space station, or d) Earth. Early demos should focus on capabilities with long-term “shelf-life,” i.e., that will still be applicable when needed. A time target is to have needed capabilities in place for a decision to be made in 2020.

Approach

- Reviewed MEPAG Goal IV and NRC Safe on Mars efforts and findings*
- Team considered broad roadmap issues associated with "Prepare for Human Exploration" aspects of Mars Exploration Program
  - Design reference mission development
  - Mars testbed missions
  - Linkages to the ISS, Lunar and Mars robotic science programs
- Reached consensus on the following 6 findings.

*Received results of 2003 JSC planning study, Drake et. al., following Lunar Roadmap Mtg. These results were not specifically addressed, but appear similar to the recent MEPAG findings.

Human Exploration Design Reference Mission Development

- Challenge: We do not know how to technically perform human Mars exploration
  - Current concepts based on high-level planning performed in late 80s and early 90s, prior to the last decade of lessons learned through Mars robotic exploration.
  - Scale of systems required for human exploration significantly exceeds (e.g., 40x for EDL) present capability.
  - A 2-3 year timeframe is required to do a thorough preliminary design level mission and flight system design that is technically feasible.
  - Without this as a guide, it is not clear how to prioritize among the many specific technologies that could be applicable to human Mars exploration.

- Recommendation 1: Human Mars exploration DRM development must be re-initiated immediately. Include personnel with Mars operational experience and human spaceflight experience into this design team.

Mars Testbed Missions (1 of 4)

- Challenge: Current program focuses exclusively on “at Mars” measurements and technology demonstrations
  - The concept of an identifiable wedge within the Mars program for the specific purpose of “Preparing for Human Exploration” is sound.
  - This funding wedge appears to be approx. right size to allow a 2020 decision.
  - A “Prepare for Human Exploration” program element that applies these funds exclusively for testbeds at Mars is a costly, risky and inefficient way to advance technology and perform verification and validation.
    - This is not the model for technology advancement within the Mars robotic program or elsewhere within the Science and human spaceflight programs.

- Recommendation 2: Apply Mars Testbed funding wedge in a manner that maximizes “Prepare for Human Exploration” measurement and technology advancement through an appropriate portfolio of:

  (1) System-studies and analyses

  (2) Ground-based testing and test-facility improvements

  (3) Flight testing in the Earth’s atmosphere

  (4) Flight testing in Earth orbit or at the Moon, and

  (5) Human precursor investigations for flight to Mars integrated as part of science missions.

Mars Testbed Missions (2 of 4)

Mars Testbed Design Challenges:

- Scaling – Building robotic systems that are roughly 2 orders of magnitude the scale of human exploration counterparts and purport to provide useful engineering information of the final flight product is challenging.
- Limited Test Quantities & Variability – Extracting useful engineering design information from 1-2 Mars tests is difficult. Are these test performed in "nominal" or "extreme" environments?
- Technology Shelf Life – Few components used by the robotic exploration program in 2010 will be usable or even producible in 2030.
- Quantitative Risk Reduction – The risk reduction from a Mars flight test must be quantified and carefully assessed relative to the cost of alternative validation approaches.

Mars Testbed Missions (3 of 4): Example "Prepare for Human Exploration" Program Elements

- System-studies and analyses
  - Human exploration EDL system
  - Artificial-gravity module
- Ground-based testing and test-facility improvement
  - TPS arc-jet testing or facility upgrade
  - ISRU laboratory testing
- Flight testing in the Earth's atmosphere
  - Pinpoint landing
  - Aerocapture
  - Mach 3 parachutes
- Flight testing in Earth orbit or at the Moon
  - Autonomous rendezvous
  - Long-term human adaptation to space environment and ECLSS
- Human precursor investigations for flight to Mars as an integrated part of robotic science missions
  - Precision landing on Phoenix
  - Radiation measurements on MSL
  - Funded addition to MTO, MSL or next Scout

Mars Testbed Missions (4 of 4)

- Performed in this manner, the “Prepare for Human Exploration” component of the MEP would gain from:
  - (a) improved data quantity and quality
  - (b) a higher degree of control of test setup
  - (c) a more resilient data acquisition & return strategy, and
  - (d) reduced test set-up cost

- Selection of the above “Prepare for Human Exploration” measurement and technology investment portfolio could be made competitively, in a Scout-like or MTP-like model, with selections made on a bi-annual basis, beginning in FY06.

- Conclusions:
  - “Prepare for Human Mars Exploration” technology advancement should be accomplished using the most cost effective strategies, across multiple venues (Earth, In-Space, Moon, Mars)
  - Mars flight test proposals must be convincing as to why a specific validation activity must be performed at Mars (e.g., relevant environment can’t be reproduced or the extraction of Mars environmental data).
  - Requires an integrated program where “Prepare for Human Exploration” investigations are competitively placed on robotic science missions.

Lunar Linkage

- Challenge: Ground rules for going to the Moon must include stepping stones for human Mars exploration.
  - A human mission to the Moon that establishes a sustained base can provide very important linkages for a human mission to Mars.
    - Heavy lift launch vehicle
    - In-space propulsion
    - ISRU fundamentals
    - Autonomy
    - Habitat design, ECLSS, telecom, power and radiation systems
    - Earth return vehicle
    - Public engagement
    - Industry, government and academia capability buildup
    - Organizational complexity (program management, systems engineering, international)
    - Understand the risk associated with human space exploration
  - Specific Human Mars Exploration requirements do not presently exist.
  - Investment in the lunar program buys down Mars Exploration risk.
- Recommendation 3: Develop Human Mars Exploration feed-forward requirements and place these upon the Human Lunar Exploration Program.

ISS Linkage

- Challenge: Maximize use of ISS as a long-term space exposure testbed of relevance to Human Mars Exploration program.
  - Long-term human adaptation to space environment (ref: Bioastronautics RM)
  - ECLSS
  - Artificial gravity centrifuge (not presently available)
  - Crew studies (maintenance, operations and repair)
  - Subsystems: lighting assemblies, hygienic systems, communication, medical equipment, avionics, O_2 generation and atmospheric control, power
- Linkages must be established from Human Mars Exploration requirements that do not presently exist.
- International commitments/partner interests.

- Recommendation 4: Utilize the ISS as a test bed for Mars exploration subsystem prototypes requiring long term exposure to microgravity environment. Develop a common supply chain that links ISS-Lunar-Mars programs.

Robotic Science Program Linkage (1 of 2)

- Challenge: Maximize technology feed-forward from Robotic Science program to Human Mars Exploration program.
  - Robotic science missions are excellent precursor testbeds for human Mars exploration
    - Interplanetary navigation and communications
    - Surface operations and infrastructure emplacement
    - Environmental characterization
    - Water and resources characterization and access
    - Autonomy
    - EDL technology (scale problem)
    - Planetary protection
  - Linkages must be established from Human Mars Exploration requirements that do not presently exist
  - Will increase the cost of the robotic science missions.

- Recommendation 5: Develop Human Mars Exploration feed-forward requirements. Prioritize these requirements for flight to Mars as an integrated part of the robotic exploration program.

Robotic Science Program Linkage (2 of 2)

- Mars Sample Return:
  - From the vantage point of a human exploration precursor, MSR is a capstone robotic mission that sets the stage for a roundtrip human exploration mission (minus ECLSS & biology, and the scale problem).
  - One or more MSR missions must precede human exploration.
    - Scientific discovery
    - Builds confidence and reduces risk of human Mars exploration
    - Identification of environmental hazards
  - While the complexity of MSR is a risk, if we can't do it we shouldn't be talking about sending human to Mars.
  - Linkages (subject to scale issues) include:
    - Earth-based analysis of Mars surface/regolith/dust hazards and toxicity
    - Design and optimization of human science activities
    - Flight systems & architectures that serve as the basis for larger scale concept study
      - Mars surface or orbital rendezvous, Mars ascent, Earth entry at Mars-return speeds
    - Public engagement and building of the Mars engineering community
    - NASA organizational complexity approaching that needed for human exploration
    - Other linkages listed for robotic science program (previous slide)

Human Exploration Requirements

- Challenge: Establish the program management and systems engineering focus required to mature the human Mars exploration program. An immediate need is requirements development and flowdown across multiple Agency programs.
  - DRM not developed to sufficient fidelity
  - Human Mars Exploration requirements do not exist
  - Advancement and program decisions being made on ISS, CEV, Lunar and Mars Robotic Science programs without benefit of the requirements from Vision's long-term goal.

- Recommendation 6: Small number of focused staff within NASA HQ program office whose sole responsibility is to develop Human Mars Exploration requirements, place these requirements on other Agency programs (ISS, Lunar, Robotic Mars), track progress and fund advancement.

Backup

MEPAG Goal IV Study: Earth Surface Testbeds

Very High

- Planetary Protection
- Connector Durability

High

- Human/Robotic Interaction
- Surface Radiation Protection (Safe Haven)
- Demonstrate In-Situ Surface Navigation

Medium

- High Energy Fission Power Systems
- Multi-use TPS analysis and ground-based testing
- Power Systems
- Life Support
- Augment DSN Capabilities
- Science Gear Technology Advances

Low

- None identified

MEPAG Goal IV Study: Earth Orbit Testbeds

Very High

- None identified

High

- Electric propulsion
- Nuclear thermal propulsion
- Advanced Photovoltaics
- In-Space Aeroshell Assembly
- Autonomous Rendezvous and Docking

Medium

- High Energy Fission Power Systems
- Van Allen Radiation Photovoltaic Materials Interaction
- Vehicle Health Monitoring and Autonomy
- Space Weather Prediction and Propagation Capability
- In-Space EVA

Low

- Chemical Propulsion

MEPAG Goal IV Study: Lunar Testbeds

Very High

- Bio-Isolation systems

High

- None identified

Medium

- Radiation Effectiveness
- Radiation Biological Interaction

Low

- None identified

MEPAG Goal IV Study: Mars Testbeds

Very High

- ISRU Atmospheric Processing and Regolith-Water Processing (series)
- Aerocapture (series)
- End-to-end system for soft, pinpoint Mars landing

High

- Continuous and Redundant In-Situ Communications Infrastructure Emplacement
- Connector Durability
- Long-term Materials Degradation

Medium

- Accurate, Robust and Autonomous Mars Approach Navigation

Low

- Deep Drilling for Water
- Bio-Plant Growth
- Autonomous Rendezvous and Docking (sensors and ISRU)
- Communications Through Solar Conjunction

MEPAG Goal IV Study: Mars Measurements

Very High
- Find and characterize accessible water
- Physical, mechanical, electrical, chemical and toxological dust properties
- Extant life characterization
- Candidate landing site characterization
- Characterization of atmospheric density and winds below 60 km over a Mars year
- Instrument (accelerometers, pressure, temperature, species) Mars atmospheric flight missions to extract data on entry system performance and atmospheric environment.

High
- Ionizing radiation surface measurement
- Radiation Shielding Ability and Mechanical Properties of the Soil/Regolith
- Traction/cohesion of Mars soil/regolith
- Meteorological properties of dust storms

Medium
- Near-Surface Thermal Environment
- Rock Size and Distribution

Low
- Measurement of Mars Atmospheric Composition for ISRU
- Mars Micrometeoroid Environment Characterization